# VEGETABLES FOR THE HOT, HUMID TROPICS

## Part 1. The Winged Bean, *Psophocarpus tetragonolobus*



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# PREFACE

In the hot, humid Tropics, torrential rains during the monsoon season create special hazards for agriculture. Lands are muddied or flooded, entrance to plantings is restricted, weeds grow vigorously, chemicals applied are washed from the plants, and fertilizer is leached from the soil. High water tables drive oxygen from the soils, diseases thrive above and within the soil, and many plants are uneconomical to cultivate. These conditions make food production difficult, and agricultural skills imperative.

During tropical rainy seasons, the problem of producing highly nourishing food still exists. For the most part, the solution is to select appropriate species and varieties and know how to grow and utilize them in both conventional and unconventional ways.

Tropical diets are often unbalanced not only because of ignorance of sound dietary principles and because of food prejudices, but also because of a lack of good species and varieties. The Tropics are exceedingly varied in this respect, but knowledge is inadequate almost everywhere. Furthermore, even when appropriate varieties are known, it is often difficult to obtain seeds.

The purpose of this series of bulletins is to furnish information about vegetables that can be grown in the hot, humid Tropics. The vegetables covered are either not well known, at least with respect to some uses, or not well distributed, but are productive during tropical rainy seasons. The techniques recommended can be applied on a small scale or with a low level of technology. Seed sources are suggested when necessary.

# CONTENTS



# ILLUSTRATIONS



# TABLES

# VEGETABLES FOR THE HOT, HUMID TROPICS

## Part 1. The Winged Bean, *Psophocarpus tetragonolobus*

By Franklin W. Martin and Herminio Delpín[1]

## INTRODUCTION

In the hot, humid Tropics, a single legume stands out as easy to grow, resistant to pests and diseases, productive, appealing to the eye and to the palate, and highly nutritious: the winged bean, *Psophocarpus tetragonolobus* (L.) DC. Some believe that it is similar to the soybean in its potential for the Tropics. Although well known and widely distributed in Southeast Asia, it is little known throughout most of the Tropics. However, three recent articles have focused attention on this species (*4, 9, 10*).[2] These publications have aroused considerable interest in the winged bean, and it is now under investigation in widely scattered regions in the Tropics and the Temperate Zone. A new publication, the Winged Bean Flyer (*12*), has been established to increase communication among persons interested in this legume.

The winged bean is most commonly used as a green vegetable harvested when the pods are about half grown (fig. 1). The leaves are also edible as a pot herb, as are the leaves of many legumes. The tuberous roots, when they occur, are also eaten. The dried seeds do not cook well, except with a special technique. They are

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[2] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

parched before eating, or a curd is prepared from the expressed juices of the soaked, ground beans, as with the soybean.

The greatest potential for the winged bean is in the home garden or in small-scale, high-intensity agriculture, because the vines need staking, bear over a long period of time, and require regular harvesting. The potential of the high-protein dried seed has scarcely been evaluated.

Accurate information on the winged bean is difficult to obtain. Much of the information given by Burkill (*1*) with respect to cultural practices is hearsay and outdated. The best source is Masefield's review (*9*), which suffers from the defects of any compilation. As an example, Masefield quotes Tindall as saying that the first pods are ready for picking 10 weeks after sowing. In fact, time to maturity is closely related to latitude and date of sowing. Similarly, Masefield implies that all plants bear edible tuberous roots. Actually, the production of edible tuberous roots depends on the variety, the method of harvest, and probably the planting date. In the absence of more exact information, Masefield's review is the best source available on the winged bean. However, information is needed from many sources covering a wide range of winged-bean varieties in order to assess more accurately the potential of this crop plant. In this bulletin, we emphasize the unique nature of the winged bean as a type of snap bean or green bean, especially for tropical regions characterized by

FIGURE 1.—Five immature winged-bean pods and one dry pod of the same variety.

heavy rainfalls. The possibility of producing a dried seed during the rainy season is also examined. The information is based on 3 years of experience with a small but cosmopolitan collection of winged beans observed in several locations in Puerto Rico.

# BOTANY

## Taxonomy and Nomenclature

The genus *Psophocarpus* (from the Greek for "noise" and "fruit," in reference to the explosive opening of the fruit when dried in the sun) includes wild, semicultivated, and cultivated species. The taxonomic relationships have not been clarified, however. The most common species is the winged bean itself, *P. tetragonolobus,* but other species have special values in limited areas.

*Psophocarpus palustris* Desv., the swamp winged bean, is a cultivated and wild species of tropical Africa, introduced to a few other regions (*13*). Occasionally its leaves, young pods, and tuberous roots are eaten, and at times its seeds, which are parched before eating. It is also suitable as a cover crop, but has little other significance. A common synonym is *P. scandens* (Endl.) Verd. The species *P. lancifolius* Harms, *P. monophyllus* Harms, and possibly others are found wild in Africa.

Some of the many common names of *P. tetragonolobus* (4) are shared with other bean species: asparagus bean, four-angled bean, Goa bean, Manila bean, Mauritius bean, princess pea, and winged bean. The term "winged bean" is becoming the most popular of the English common names.

## Origin and Distribution

The geographical origin of the winged bean is still uncertain. Burkill (*1*) believes that the historical and nomenclatorial evidence points to an African origin, perhaps Madagascar. But the center of variation now seems to be Papua New Guinea (*8*). In Indonesia and Papua New Guinea, hundreds of varieties exist with significant variation in all principal characteristics. It is difficult to believe that such variation developed after introduction of one or a few varieties. The Burmese varieties, grown chiefly for their tuberous roots, are somewhat different from the varieties of Papua New Guinea and may in fact represent more highly evolved and selected types.

The winged bean was well distributed in southern Asia from India to the islands of the Pacific in pre-Columbian times. It is an important vegetable in India, Ceylon, Burma, Thailand, Vietnam, the Malay Peninsula, and the Philippines. It is especially important in the highlands of Papua New Guinea. Although found through-

out tropical Africa, it is not especially important there. It has been introduced to the New World, but it is found only sporadically through the Caribbean and the American Tropics.

## Description

The winged bean is a perennial herbaceous vine that climbs by twining to the left (fig. 2). Nevertheless, many plants die during the dry season, and the winged bean is generally grown as an annual. Since the winged bean is a short-day plant, flowering occurs as day length shortens to the minimum necessary for the variety, and thus overall appearance varies with season. The bulk of viny growth may be enormous, and heights of 5 meters or more are easily obtained. Some varieties (extreme short-day types) are principally herbaceous in growth habit, and others (day-neutral types) are mainly pod bearing. The stem is thin but reaches 1 centimeter in diameter in older plants. Trifoliate leaves are borne alternately on erect, stiff petioles, and are subtended by a short

FIGURE 2.—A winged-bean plant climbing a bamboo pole.

stipule. The three leaflets are similar and range in shape from oval to ovate-lanceolate. The base is acute, obtuse, or somewhat cordate, and the blade is extended to an acute or acuminate tip. The margins are entire. The leaves may be pubescent or glabrous, and the petioles and stems may be tinted with anthocyanin.

FIGURE 3.—Mature but not dry pods of different varieties of winged bean.

Terminal or axillary racemes up to 15 centimeters long bear two to many flowers. The calyx consists of five sepals united into a tube of two lobes. The standard petal is large, with basal lobes or auricles, the wings are narrow, and the keel is incurved. Stamens of varying length are united in a tube of 10. The style is thickened, and the stigma is densely pubescent. The ovary is long and tapering. The flowers vary from white through blue to purple, and the distribution of the blue coloring varies. Flowers have been reported to open in the morning in Ghana, but in the afternoon in Papua New Guina (*11*).

The pod of the winged bean is highly variable (fig. 3). Details of variations found have been given by Khan (*6*, *7*), but in some cases the ranges he reports are inadequate. Lengths range from 6 to 40 centimeters, and widths from 1.2 to 4 centimeters. The pod may be square or rectangular (flattened) in cross section. It is often colored dark red or purple by anthocyanins. The wings vary in size and shape. They may be relatively narrow, with entire margins, or wide and thick, with undulate margins. The fiber within the pod varies. In better varieties the wings as well as the fiber are reduced.

The number of seeds within the pod varies from 5 to 40. The seeds are spherical, weigh from 0.05 to 0.45 gram, and vary in color from white to tan to dark brown or almost black. Seed color

FIGURE 4.—Root nodules of the winged bean.

is influenced by anthocyanin and tannin contents and by the environment during maturation.

The fibrous roots of the winged bean are numerous but somewhat shallow. They are characterized by large numbers of nodules up to 1 centimeter in diameter, where fixed nitrogen is stored (fig. 4). The roots tuberize in some instances, in which case they are more or less spindle shaped, often irregular, and not attractive. The tubers are fibrous, starchy, edible, and generally small, weighing seldom more than 50 grams. The tendency to tuberize is a varietal characteristic. Apparently, tuberization can be promoted by frequent harvesting of the pods, but much study is needed on the circumstances promoting tuber production and reabsorption.

# VARIETIES

## Variation

The winged bean is a genetically diversified species that exhibits a wide variety of easily classified or continuous characters. Among the first 26 accessions introduced at the Mayagüez Institute of Tropical Agriculture (MITA) (table 1), 64 types were found. However, many of these differed only in simple characteristics, such as flower or seed color, that might be found in any segregating population.

The principal variation found so far is in the following characteristics:

Seed color.
Seed size.
Ring around hilum.
Hard seed (poor germination without scarification).
Vigor of vegetative growth.
Dwarf or normal stature.
Response to long days in Puerto Rico.
Tuberous root production.
Degree of nodulation of roots.
Anthocyanin of stem.
Size of leaves and leaflets.
Flower colors.
Flower color distribution.
Pod colors.
Pod color distribution.
Pod length.
Pod width.
Smoothness of pod surface.
Number of seeds per pod.
Cross sectional shape of pod.
Development of wings.
Undulation of wings.
Dry pod weight.
Total yields.
Perennial versus facultative annual growth habit.
Drought resistance.
Hardness of seeds when cooked.
Bitterness of cooked seeds.
Protein content.
Oil content.

## Varieties for Special Purposes

Because the winged bean has been grown outside of organized Western agriculture, named varieties are almost unknown in the scientific literature. Such varieties do exist, but knowledge of indi-

vidual varieties and their characteristics is not widespread. Certain facts have already emerged.

The varieties from Papua New Guinea, and to a lesser extent from Indonesia, are the most diverse and the least improved. Several classes of varieties can be distinguished:

Wild varieties, with small, fibrous pods.
Improved varieties with large, coarse pods.
Dual-purpose varieties, or varieties used chiefly as a source of tubers.
Highly improved varieties with thin pods and narrow wings.
Varieties that produce chiefly foliage, and therefore are useful as forage.

Of course, there is a continuum among varieties, and no strict division into classes. The varieties seen in Java and Thailand are

TABLE 1.—*Winged-bean varieties evaluated in Puerto Rico*

[Mayagüez Institute of Tropical Agriculture (MITA)]

| MITA No. | Source | Other identification | Uniformity of the accession |
|---|---|---|---|
| WB–1 | Trinidad | WB–27 | Uniform. |
| WB–2 | Indonesia | 503, WB–28 | Do. |
| WB–3 | .... do | 502, WB–29, Bogor | Do. |
| WB–4 | Papua New Guinea | Chimbu | Do. |
| WB–5 | .... do | OPS–31 | Separated into 2 lines. |
| WB–6 | .... do | OPS–48 | Separated into 3 lines. |
| WB–7 | .... do | OPS–58 | Separated into 5 lines. |
| WB–8 | .... do | OPS–76 | Uniform. |
| WB–9 | .... do | OPS–58 | Selected from WB–7. |
| WB–10 | Nigeria | TPt–1 (IITA)[1] | Separated into 4 lines. |
| WB–11 | .... do | TPt–2 | Separated into 2 lines. |
| WB–12 | .... do | TPt–3 | Separated into 4 lines. |
| WB–13 | .... do | TPt–6 | Uniform. |
| WB–14 | .... do | TPt–7 | Do. |
| WB–15 | .... do | TPt–8 | Separated into 2 lines. |
| WB–16 | .... do | TPt–9 | Separated into 3 lines. |
| WB–17 | .... do | TPt–10 | Separated into 9 lines. |
| WB–18 | .... do | TPt–11 | Separated into 2 lines. |
| WB–19 | .... do | TPt–12 | Separated into 3 lines. |
| WB–20 | .... do | TPt–10–1 | Separated into 5 lines. |
| WB–21 | .... do | TPt–10–2 | Separated into 6 lines. |
| WB–22 | Costa Rica | PI 338610 | Uniform. |
| WB–23 | Indonesia | 785 | Do. |
| WB–24 | .... do | 7992B | Do. |
| WB–25 | .... do | 933 | Do. |
| WB–26 | .... do | 1102d | Do. |

[1] International Institute of Tropical Agriculture, Ibadan, Nigeria.

TABLE 2.—*Characteristics of selected varieties of winged bean*

| MITA No. | Name[1] | Seed color | Pod length (cm) | Pod characteristics | Photoperiodism | Yield |
|---|---|---|---|---|---|---|
| WB–2 | Bogor | Tan | 18 | Smooth, reduced wing, green | Reduced | High. |
| WB–4.2 | Chimbu | Brick red | 26 | Straight, square, undulate wings, purple. | Principally winter flowering. | Medium. |
| WB–10.1 | Butterfly | Tan | 30 | Undulate, heavy wing, green with purple edges. | Winter flowering only | Very high. |
| WB–10.3 | Mariposa | Brown | 33 | Straight, undulate, heavy wings, green with purple. | do | High. |
| WB–11.2 | Ribbon | do | 20 | Flattened, undulate, redueed wings, green. | Reduced summer flowering. | Do. |
| WB–12.8 | Always | Tan | 27 | Flattened, undulate, reduced wings, green with light-purple wings. | Flowers year round | Do. |
| WB–12.11 | Siempre | Brown | 33 | do | do | Very high. |
| WB–15.12 | Lunita | Brick red | 16 | Flattened, curved, undulate wings, purple. | Winter flowering only | High. |
| WB–18.1 | Dual | Tan | 22 | Flattened, curved, undulate wings, green. | Principally winter flowering. | Low. |
| WB–19.9 | Toaño | Light yellow | 16 | Flattened, straight, undulate wings, green. | Flowers year round | High. |
| WB–21.8 | Tinge | Dark purple | 19 | Flattened, straight, small, smooth wings, bordered with purple. | do | Do. |
| WB–22.8 | Alipasto | Dull red | 14 | Flattened, curved, undulate, wide wings, green. | Winter flowering only | Very low. |

[1] Names assigned at MITA for convenience.

principally of the highly improved types and are excellent vegetables. The varieties of Burma are less known to us, but they include forms that produce tubers.

It is not yet clear what constitutes a variety of the winged bean. This uncertainty reflects, in large part, incomplete knowledge of the breeding system. The winged bean is self-fertile, but self-pollination is not automatic. Large wild bees are attracted to the flowers and increase self-pollination and sometimes cause cross-pollination. On the basis of current knowledge, it is best to consider the winged bean as a normally self-pollinated crop with a small amount (perhaps 5 to 10 percent) of cross-pollination.

If this is true, the winged bean is ideally suited to long-term evolutionary change or breeding by mass selection. To the grower this reproductive system suggests that varieties will not necessarily be uniform. A few off-type plants resulting from hybridization and segregation can be expected. In certain regions such as Thailand, however, selection for improved horticultural types may already have resulted in fairly uniform but somewhat heterozygous varieties. Growers can improve their stock by eliminating plants with undesirable characteristics as quickly as these are recognized.

Certain varieties stand out in our 2-year trial as especially valuable (table 2). These varieties did not originate at MITA, but varietal names were assigned as a matter of convenience. The variety Bogor (WB–2), the standard type seen in the markets of Southeast Asia, produces over a long season if well cared for during the spring and summer. It is perennial in habit and shows continued production after 2 years. Similarly, the variety Ribbon (WB–11.2) produces well but chiefly during the winter. The varieties Butterfly (WB–10.1) and Mariposa (WB–10.3) are typical of the heavy-bearing, square-podded winter types. The variety Lunita (WB–15.12) is similar but with a flattened pod. The varieties Always (WB–12.8) and Siempre (WB–12.11) are year-round varieties in Puerto Rico, as is also Toaño (WB–19.9).

Some varieties produce principally foliage in Puerto Rico. The variety Alipasto (WB–22.8) is good in this respect and produces only enough seeds for maintenance. Dual (WB–18.1) produces a large amount of foliage and sufficient seed also during the winter.

Chimbu (WB–4.2) is a good variety for seed production, although its purple pod is less than acceptable as a green bean.

The variety Tinge (WB–21.8) is the best found for use as a dried seed. When seeds were soaked in a solution of sodium bicarbonate (see later), more than 95 percent softened on cooking and were very palatable.

# CULTIVATION

## Climate Requirements and Annual Cycle

The winged bean is a perennial plant capable of living and bearing seeds for several years. Nevertheless, it is most frequently grown as an annual. Drought, over bearing, and disease can lead to premature death of the plant after the first season of production.

Plants flower during short days. The photoperiod appropriate for stimulating flowering varies but does not seem to be extreme. In Puerto Rico (lat. 18° N.), day lengths vary from 11 hours at the beginning of the dry season to 13 hours at the beginning of the rainy season. The winged bean can be planted at any time of the year. Varieties differ in sensitivity to day length. When planted during the short days, most varieties will flower within as few as 8 weeks. Others require several months or do not flower until suitable size and maturity have been acquired. Vines with as little as 30 centimeters of growth have flowered in Puerto Rico. When planted during the season of long days (12–13 hours), most winged-bean varieties will develop considerable vine growth before flowering begins. When days shorten, flowering is induced and is likely to be abundant. If green pods are removed periodically, flowering can continue for about 8 months. In Puerto Rico, some varieties have been found that flower all year round, but even these flower more vigorously during short days.

The winged bean thrives in tropical monsoon climates. Rains that quickly destroy most other beans stimulate the winged bean to flourish. Pods are not usually damaged by rains, although minor fungus infections have been seen in Puerto Rico. On the other hand, the winged bean can accommodate short periods of drought. Prolonged periods without sufficient rain will kill the plants. Unless irrigated, the winged bean is not suited to dry regions.

Little is known about the tolerance of the winged bean to high altitudes of the Tropics. Although reported to be grown at altitudes of up to 2,000 meters in Papua New Guinea, the crop is better suited to tropical lowlands.

## Seeds, Soils, and Spacing

The seeds of some varieties of winged bean do not absorb water freely. When varieties are selected, it is desirable that the seeds absorb water so that they can be cooked, or so that germination is uniform. Scarified seeds germinate much better than unscarified seeds. Good seeds can be planted at any time of the year and germinate in 5 to 15 days. Seeds are not normally inoculated, but in one test at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, yields were higher after inoculation. Cross-inoculation experiments have shown that the strains

of *Rhizobium* that induce nodulation of cowpeas are also successful with the winged bean (3).

The soils for the winged bean can be extremely varied. The winged bean will tolerate heavy soils and poor drainage and is therefore often grown along riverbanks. The plants are less vigorous and more susceptible to nematodes in sandy soils, but the tuberous roots are larger. The winged bean can grow successfully in infertile soils, probably because of its nitrogen-fixing capacity.

The soil for the winged bean should be plowed, disked, or turned by hand before planting. Organic material incorporated into the soil promotes growth over a long period. If this is not possible, a small amount of balanced mineral fertilizer should be added to the line of plants or to the planting site (250 kilograms per hectare). If the soil is likely to be flooded, planting on ridges is desirable. Once established, the winged bean seems capable of fixing sufficient nitrogen for growth, but fertilizer requirements otherwise are still unstudied.

Spacing of about 1.5 meters between rows is necessary for collection of the pods. Plants can be spaced within the rows about 1 meter apart.

## Postplanting Care

Because winged-bean seeds usually germinate late and because the young plants grow slowly, the planting needs special care for several months. It is particularly important to maintain the planting free of weeds. Although weed control can be done with commercial herbicides used for other beans, appropriate herbicides for the winged bean need to be determined. Traditional methods of weed control—by hand, by hoeing, and by the use of a mulch—are suitable for small plantings. Particular care should be taken to destroy weedy vines that can climb the support pole and shade the winged beans. Once the foliage is well established, weed control will still be necessary to reduce the competition between weeds and crop plants.

If rains are not frequent enough, irrigation will be necessary. Weekly irrigations are desirable until the plants are large and have roots deep enough to resist short droughts.

A few weeks after germination, the twining vines appear. From the beginning they will need support. Some supports provided for the mature vines, such as thick bamboo poles, are too coarse for the fine vines. Therefore, the young plants should be furnished with some kind of fine support, such as a slender branch, until vigorous vines are produced.

The type of support furnished can vary. Individual supports of simple poles 1.5 to 2.0 meters in height have proven satisfactory. Wire fencing is sometimes used but is unnecessary and costly.

A Y-shaped trellis connected by wires between the extremes, with strings between the wires, permits a row of plants to grow at an angle following the strings. The pods hang below the strings and are easily harvested. Vines grown for tubers are unstaked in Burma. Experience at MITA has shown that most varieties grow vigorously only when staked.

Little information is available on the diseases of the winged bean and their control and on insects and other pests of the winged bean. In small plantings, only minor disease and insect problems have been encountered in Puerto Rico. Disease and insect problems would certainly increase in large plantings. As such conditions occur, controls may be necessary. These controls should first involve commonsense measures such as the avoidance of sandy soils when problems of nematodes occur, rotation of the plantings to avoid buildup of disease, elimination of plant residues by burning or composting if diseases or insects have occurred, and prompt diagnosis and treatment of disease and insect problems. In the home garden, insecticidal treatments are often not economical and are dangerous. In commercial plantings, insecticides should be reduced to a minimum.

The winged bean is often grown with other crops. These may afford a degree of protection from insects. Suitable intercrops, such as sweetpotatoes and pumpkins, need study.

Some types of damage reported on winged-bean foliage are: (1) consumption of the foliage by geese and chickens, (2) infestation of foliage with red spider mites, (3) tunneling of the leaf by leaf miners, (4) eating of the leaf by caterpillars and grasshoppers, and (5) damage to young pods by caterpillars. In addition, the following diseases have been mentioned in the literature: leaf spots, rotting of the stem at the crown, and a fungus on the large pods. Kahn (*6*) has summarized the pests that attack the winged bean in Papua New Guinea as follows: the cowpea aphid (*Aphis craccivora*), the ladybird (*Henosepilacha signatispennis*), *Maruca testulalis*, an unidentified leaf miner, and root knot nematode (*Meloidogyne* spp.). The diseases are false rust (*Synchytrium psophocarpi*), leaf spot (*Cercospora psophocarpi*), *Sclerotium* spp., and *Colletotrichum lindemuthianum.*

## Yields

Yields of the various edible parts of the winged bean are reported in such a fragmentary fashion that it is difficult to get a clear idea of the potential of the species. Furthermore, it is difficult to rely on published data that are so scanty. Yields of edible leaves and mature green seeds have not been reported. In Puerto Rico, extended regular harvest of one variety yielded 4 tons per hectare, believed to be a conservative yield. Seed yields have been reported

from 0.7 to 2.2 tons per hectare, and in small plots in Puerto Rico, seed yields ranged from 0.38 to 2.9 tons per hectare, averaging 1.40 tons per hectare. The average yield of protein in Puerto Rico was 479 kilograms per hectare. Yields of tubers can reach 4 tons per hectare, a low yield for a tuber-bearing crop. Heavier yields can be expected as appropriate varieties are selected.

Because the winged bean is only now being intensively studied, it should be possible to improve yields by careful selection of varieties and by means of better agronomic practices.

## USES, COMPOSITION, AND NUTRITIONAL VALUE

The winged bean produces several different organs of value as food. It is sometimes said that all parts of the plant are edible. This is an exaggeration, for the wiry stems, the fibrous roots, and the dried pods would be difficult to eat under any circumstances. But the leaves, flowers, young pods, immature green seeds, mature seeds, and tuberous roots are edible. Several other legumes share this flexibility. Thus, when one talks about the winged bean as a food, one must specify which organ is under consideration. Only when the many uses of the winged bean are considered and compared to those of other plants is it possible to say whether the winged bean is a superior species, as compared to soybean for example.

The composition of winged-bean organs has been reviewed by Claydon (2), who has collected and summarized the fragmentary reports throughout the literature. Because better data are not available, the summary of Claydon is the source of most of the commentary that follows. Data available from MITA experiments are also included here.

### Leaves

The leaf of the winged bean (fig. 5) is edible as a cooked, spinachlike dish. The young leaves of large, maturing plants can be used at any time, but especially during the off-season when vegetative growth is abundant and the plants are not in bloom. The periodic harvest of up to 10 percent of the foliage is not likely to reduce flowering and seed yield. During the period of production of pods, only light harvesting of leaves should be done. Leaves can be best prepared for eating by steaming or frying with batter to avoid loss of vitamins. The leaves should not be eaten raw. Boiling in large quantities of water is not recommended because soluble vitamins and minerals are easily lost.

Leaves in general are of excellent nutritional value: high in protein, low in fats and carbohydrates, high in vitamin A, and

sometimes high in vitamin C. Leaves contain moderate amounts of other vitamins and minerals. The leaf of the winged bean is relatively high in protein, about 25 percent (2), compared to other classes of leaves, but about average for the leaf of a leguminous plant. Since flowers are a relatively minor portion of the edible material of the plant, and since they are usually cooked with the leaves, it is not necessary to consider them separately.

### Immature Pods

The young pods, when one-half to three-quarters grown, are tender and edible. They grow rapidly after the flowers are produced and reach their mature size in about 21 days. As the pods begin to mature, they lose their shiny appearance and develop

FIGURE 5.—Winged-bean leaf and shoot tip suitable for use as a spinach dish.

fiber. Experience will show which pods are mature and cannot be used entire. In the kitchen, those pods that cannot easily be broken by hand are overmature. Pods that are too old to cook entire may be used as a source of green beans (see later). The young pods, whole or sliced, can be eaten raw. The pods are best cooked by steaming or by boiling in water a minimum of 10 minutes. When the pods are soft enough, they are seasoned and served. Contrary to what has been written, the cooked pods are not crunchy but tender and have a distinct, somewhat bitter flavor.

The pod is reasonably nutritious when cooked entire, and in fact can be best compared to snap beans. As with all fresh vegetables, its chief component is water. On a dry-weight basis its protein content is good, about 20 percent (2). It contains considerable carbohydrate and little fat. Pods with suppressed wings are richer in nutrients than pods with thick, well-developed wings, and so the appropriate pod characteristics are important in selecting a good variety. The immature pod is probably the most important part of the winged bean now in use. This usage led the authors to consider the winged bean as probably the principal species of bean for the hot, humid tropical lowlands. However, other immature beans are often preferred in flavor to the winged bean, such as the kidney bean, *Phaseolus vulgaris* L., and the cowpea, *Vigna unguiculata* (L.) Walp.

At MITA, a study of the protein content of the winged-bean pod and seeds during the various stages in which it could be considered edible showed that the bulk of the dry weight (90 to 95 percent) is in the pod. The protein of the pod tended to decrease with maturity as the dry weight and protein content of the seeds increased (table 3). Although the developing seeds were rich in protein, the overall protein content of seeds and pods was only intermediate, about 15 percent on a dry-weight basis. When the entire green pods are eaten, the bulk of the protein comes from the pod, not the seed.

TABLE 3.—*Changes in protein content of winged-bean pods during growth*

| Pod stage | Pod length (cm) | Dry weight (g/100 g fresh) | | Total protein content (g/100 g fresh) | | | Protein content (%) | |
|---|---|---|---|---|---|---|---|---|
| | | Pods | Seeds | Pods | Seeds | Total | Pods | Seeds |
| Immature | 10.1 | 13.8 | 0.6 | 2.26 | 0.14 | 2.40 | 16.4 | 23.6 |
| Mature | 13.8 | 12.0 | .8 | 1.87 | .18 | 2.05 | 15.6 | 22.4 |
| Mature but stringy | 15.6 | 17.4 | 1.3 | 2.47 | .32 | 2.79 | 14.2 | 24.2 |
| Overmature | 19.4 | 17.0 | 1.7 | 2.38 | .48 | 2.86 | 14.0 | 24.6 |

## Mature Seeds

When the pods are too fibrous to be eaten, the seeds themselves can be eaten (fig. 6). They should be removed from the pods before they are served, or each person can open the pods by hand at his plate. The mature seeds have a strong but pleasant bean-type flavor and may be somewhat bitter.

The mature seeds approach the dried seeds in nutritional value. Naturally, their nutritional value increases with maturity. The protein content (dry-weight basis) of mature, shelled seeds was found to be 38.6 percent, the fat content 18.6 percent, and the total carbohydrate about 38 percent. Studies have not been made to determine the constitution in mature seed of toxic substances normally found in the dried seeds (see later).

In contrast to the more popular pods, the mature seeds might provide the best nutritional value of the winged bean. Considerable protein is accumulated by the seeds as the pods continue to grow, and so it might be wise, nutritionally speaking, to use mature seeds in place of the pod. After the pods reach a stage too large and fibrous to be used as snap beans, the seeds can be removed and cooked as is customary for certain peas and lima beans, or they can be roasted.

## Dry Seeds

Winged-bean pods can dry with a minimum of fungal problems even during the rainy season. When the pods are brown, they can be picked and dried thoroughly in the sun. They sometimes shatter when dried. This should be avoided so that seed is not lost, but may be advantageous under certain circumstances.

The dried seed (fig. 6) can be stored for long periods under cool, dry conditions. Winged-bean seeds are seldom boiled as other beans are. They soften slowly in water and sometimes re-

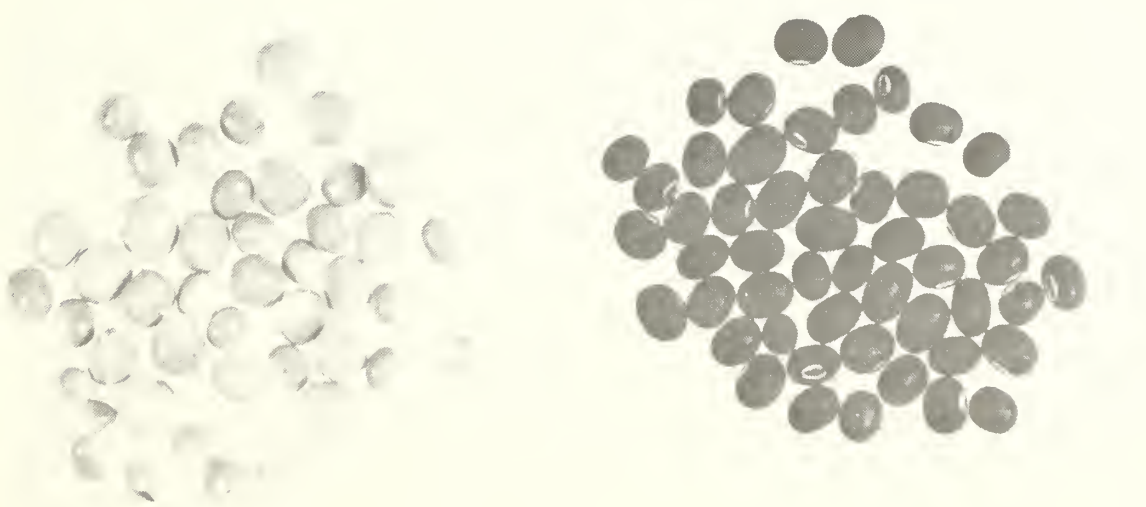

FIGURE 6.—Mature green seeds (left) and dry seeds of the winged bean.

quire days to swell. During softening, brownish pigments, possibly tannins, are released. When such seeds are cooked, long boiling times (3 to 4 hours) are required before seeds soften sufficiently. However, even hard seeds that do not absorb water eventually soften. The flavor of cooked seeds is strong and disagreeable to some people. A mouthful of winged beans is distinctly chewy. In normal portions, the cooked beans apparently are not harmful, but do produce flatulence.

At MITA, the following technique is used to prepare dry winged-bean seeds for eating. The seeds are placed in 5 volumes of water containing 1 percent sodium bicarbonate, boiled 3 minutes, and left to soak overnight. The soaked seeds are washed and boiled in 3 volumes of water for 25 minutes. They are then soft and free of harsh flavors.

Ripe seeds are sometimes roasted. The best product is obtained by soaking and softening the seeds first and then roasting them. The roasted seeds may be ground into a meal as a cereal.

The nutritive value of the dried seeds is higher than other beans except soybeans. In tests of 32 seed lots, protein content varied from 29 to 41 percent, and oil content varied from 14 to 19 percent.

The protein of the seed is known to be somewhat deficient in the sulfur-containing amino acids, methionine and cystine. This deficiency is true of the proteins of other beans as well. Similarly, the protein of the winged bean is rich in lysine, as is that of other beans. The rich nutritive value of winged-bean seeds is in the high percentage of protein, not in any distinctive amino acid pattern. As with other beans, winged beans would be a useful complement to a grain-based diet.

A great potential for the seeds is in the production of curds, or tofu, as with soybeans. The seeds are soaked and finely ground, and a protein-rich "milk" is derived. The milk is coagulated, and from the curds a variety of products are made. No fermentation is involved. The winged bean has been reported to be used in such a process. In tests at MITA, vegetable curds produced were edible but grayish yellow, chalky, and inferior in flavor to vegetable curds made from soybean. More study is necessary to develop a process suitable for home production of vegetable curd. Winged-bean seeds should be useful for sauces and other fermented products.

The oil of winged-bean seed is characterized by a high percentage of unsaturated fatty acids (*11*) and is thus of high nutritional value. When expressed or removed by solvents, it should be a good oil for salads or cooking, and could be processed into margarine. Although the proportions of the various fatty acids of winged-bean oil are not comparable to those of soybean, the nutri-

tional value and use of the oil should be about the same. Winged-bean oil has been reported to contain 13 to 15 percent of behenic acid, a saturated fatty acid found only in traces in soybean.

Many seeds of edible legumes contain toxic substances. The presence of these in the winged bean has been summarized by Claydon (2). The principal toxic substances so far discovered are hectin (a substance that agglutinates red blood cells), a trypsin inhibitor, hydrocyanic glycosides, and tannins. These substances, acting together, have killed rats in experimental feeding tests. However, the strong techniques needed to prepare beans for cooking (prolonged soaking and boiling) are believed to inactivate or eliminate toxic substances. The presence and significance of tannins in winged-bean seeds have not been adequately investigated. These metabolic inhibitors reduce the biological value of protein.

Jaffé and Korte (5) found amylase and trypsin inhibitors and hemagglutinin activity in winged-bean seeds. Ground, raw seeds were toxic to rats (this is true of many bean seeds, including those of *Phaseolus vulgaris,* the kidney bean). However, cooked seeds supported normal growth.

Although the winged bean is promoted on the basis of the high protein content of the seed, the value of the seed as a human food is limited by taste factors, human preferences, and possibly by toxic substances. The use of sodium bicarbonate to soften the seed needs additional study, particularly to see if B vitamins are destroyed and if proteins can be freely utilized. Much more study is needed of the seed and its utilization. Varietal differences are suspected which may make selection possible for more palatable seed types.

## Tuberous Roots

When tubers (fig. 7) are present, they can be steamed or boiled and served as a starchy vegetable. The cooked tuber can be mashed and sieved if too much fiber is present. The tubers are agreeable in flavor to young and old alike, and are said to be used as baby food. However, not all varieties produce tubers, and the tubers are often small. The amount of protein produced in the roots may be small compared to that produced in the seeds, and very small compared to that produced in the leaves.

Reports on the nutritional value of the tubers are not reliable. The figures quoted by the National Academy of Sciences, 12 to 15 percent protein, wet-weight basis, more than 20 percent, dry-weight basis (*10*), suggest a high protein content. The most recent report by Claydon (2) of a protein content of 25.1 percent, dry-weight basis, seems to confirm these figures. But the figures seem unrealistically high. Tuberous roots are storage organs for starch. Protein contents on a dry-weight basis vary from 1 to 2 percent in

cassava to 13 to 15 percent in exceptional yam varieties. It can be expected that winged-bean tubers normally will contribute chiefly starch and little protein to the diet. The question of the protein content of winged bean tubers must be considered open.

## PROSPECTS FOR THE FUTURE

The winged bean, as it now is, is an excellent vegetable for production in the home garden and for the market. The winged bean has immediate worth, and efforts should be made to popularize it and to distribute seeds widely. Although especially adapted to the hot, rainy season and coastal regions, it should be possible to select varieties for year-round production and for adaptation to specific environments, including tropical highlands.

Still, the long-term potential of the winged bean as a dry legume for the wet Tropics is untapped. Hard seeds, excessive tannins, and possibly other toxic substances already known in the

FIGURE 7.--Typical winged-bean tubers.

seed impede usage. Two chief kinds of investigations are necessary: one to select better seed from varieties already collected, and another to find better techniques to cook the dried seed of existing varieties. The effects of sodium bicarbonate on cooking of seed need more study. Until such studies are done, it is unlikely that the dried seeds will be widely used.

Because it requires staking and harvest by hand, the winged bean is a labor-intensive crop. However, this is not a disadvantage in many parts of the Tropics. The needs of the plant are simple, and so it is suited to a low level of technology. The year-round production, at least of some varieties, is a marked advantage of the crop for small-scale production and use.

The processing potentials of the winged bean, particularly as a snap bean substitute, need some investigation. Beans of appropriate varieties should be useful either canned or frozen.

The future of the species as a source of roots and edible leaves does not appear bright. The tuber production is too low, in spite of reportedly high protein contents, and as a leafy vegetable, the winged bean competes with too many other species available everywhere.

International efforts begun with the winged bean may well determine its future. The Winged Bean Flyer (*12*), a newsletter for winged-bean researchers, is being published by the University of Illinois, Urbana, Ill.

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